HEALTH RISK RELATED TO PESTICIDE EXPOSURE IN THE AGRICULTURE SYSTEM IN THAILAND: A SYSTEMATIC REVIEW

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ABSTRACT:

Agricultural use of pesticides has increased in Thailand in recent decades due largely to Thailand's major role as a leading exporter of food. There is evidence of the adverse effects of pesticide exposure and health risk on Thai rice, chili and maize and other vegetable farmers. However, limited information is available about which cropping systems pose the greatest exposure risk to farmers and their families. This systematic review was aimed at comparing the data of scientific articles on pesticide exposure of agricultural systems in Thailand. Original articles from Pubmed, The Journal of health Research and Science direct were compared focusing on adverse health effects, risk perception and proper prevention practices by farmers themselves. Articles were from Jan 2009 till Jan 2016 and most studies on organophosphates (OPs) show that farmers do suffer from adverse health effects while children are also exposed indirectly. Most studies reflect on the results of pesticide exposure being the result of improper use of personal protective equipment (PPE) and suggest guidelines and management strategies be implemented to increase the knowledge attitude and practices of farmers. In conclusion, hazard quotient (HQ) levels in most chili studies suggest that residue of Profenofos on chilies was higher than the acceptable level suggested by the hazard quotient (HQ > 1) and exceed acceptable risk. However, based on acetylcholinesterase (AChE) and pseudocholinesterase (PChE) levels in farmers the research suggests that rice farmers have a higher risk of adverse health effects than chili, maize and other vegetable farmers.

Keywords: Pesticide exposure, Agricultural system, Systematic review, Thailand

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INTRODUCTION

Previous study on health conditions and safety at work found that rice farmers were exposed to four types of health hazards: physical, biological, chemical and ergonomic. In a study conducted in Pathumthani province, Thailand. The evaluation of Knowledges, Attitudes, and Practice (KAP) of farmers in Klong 7 sub-district regarding to occupational agricultural health and safety showed that farmers had averaged to high level of knowledges both before and after model implementation. However, their knowledges did not reflect their behavior. Their behavior still showed high risk both before and after the implementation [1]. To be effective it is necessary to understand the rationale for farmer misuse, or overuse, of pesticides. Chili farmers could be exposed to pesticide through multiple pathways; dermal, inhalation and accidental ingestion, during performance of their tasks. Dermal might be the most important exposure route [2]. Although the use

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of pesticide has already been documented to have adverse effects to human health, misunderstanding and misusing are still widely found in rural areas. Pesticide-related health problems usually manifest as a series of symptoms depending on severity of exposure.

Pesticides pose serious health concerns and risk in Thailand. These risks are arising due to the exposure of farmers when either mixing or applying pesticides and even working in treated fields. Exposure from residues on food and in communal drinking water for general populations has also become a huge cause for concern. Accidental poisoning has been the result of these activities and the routine uses of pesticides have posed a major health risk to rice, chili and maize farmers in Thailand. Farmers in developing countries face great risks of exposure due to the misuse of toxic chemicals. For one, these chemicals are normally banned or restricted in other countries with the addition of incorrect application techniques, poorly maintained or totally inappropriate spraying equipment, inadequate storage and misguided use of personal protective equipment , and often the reuse of old pesticide containers for food and water storage increase exposure.

Rice production as well as chilies and maize are important for the Thai economy and for the labor force. The total production of rice in Thailand has increased from 29.5 million tons in 2003 to 37.9 million tons in 2012, and at the present time 25.7 million acres of paddy fields are under cultivation. As a result, increasingly more pesticide is being used to increase production yields. Organophosphates and carbamates protect crops from insects and are usually wildly found among insecticides in Chili and Rice cropping systems. With the increasingly growing use of pesticides in Thai agricultural practices we have seen many health related risks associated with the health of occupational farmers. For example The Disease Control Department of northern Thailand reported that 13.54 per 100,000 people in northern Thailand are hospitalized due to pesticide poisoning from farming. Most poisoning cases are related to the use of OPs, followed by herbicides and carbamates [3]. Pesticide exposure may cause acute health effects. The acute effects include dizziness, blurred vision, nausea, vomiting and some muscular weakness and numbness. However there is a gap in this research for low level exposure due to inconsistency of assessments.

Several publications exist for health symptoms among farmers. However, the gap in the research points to the association between symptoms and agricultural tasks on a farm because they have never been well established. Most studies have been done on exposure without taking into consideration the actual tasks that some farmers are responsible for. If you look at the relationship between exposure and tasks we can concur that different tasks account for different exposure concentrations and time frames. Some of the tasks performed in the fields consist of spraying, mixing pesticides, scattering seeds and harvesting crops. The risks and consequences of being directly exposed to pesticides may differ according to the task and doses used in that task, resulting in different symptoms. Therefore, the aim of this study was to investigate the potential health risks related to pesticide exposure in agriculture systems; compare exposure occurrences between different cropping systems.

MATERIALS AND METHODS

Search strategy

A systematic review of articles in PubMed, Science Direct, Asia-Pacific Journal of Public Health and The Journal of Health Research (Thailand), were carried out using the following search words or text word combinations: “Health Risks” “Risk Behavior”, “Pesticide Exposure, Thai vegetables, “chilies”, “maize” and “rice.” Data used was data collected from different methods of collection such as focus groups, interviews and observations. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used to determine the data sought through database searching [4]. Agricultural practices factor into how much exposure farmers and their families are susceptible to and how exposure is related to potential health risk.

Inclusion criteria

Using PRISMA the articles selected for the review met the following inclusion criteria: (a) original articles; (b) written in English; (c) carried out in Thai farmers and their families; (d) evaluating the summaries of pesticide exposure on agriculture systems [4].

Data analysis

The methodological quality of the studies included in the review was assessed using the (PRISMA) checklist [PRISMA]. A summary of data was collected from 36 different articles pertaining to pesticide exposure, Thai agriculture and risk

Table 1 Studies on health risk and pesticide exposure

References	Province	Study design	N	Age (years)	Biological samples/timing
Santaweesuk, et al., 2013 [1]	Nakhon Nayok	Cross-sectional study (C)	145	50	Face - to - face interview questionnaire.
Sapbamrer and Nata, 2014 [3]	Ban Tom sub-district, Nan	C	182	18 and 75	EDTA tube for measuring whole blood AChE activity
Raksanam, et al., 2014 [5]	Khlong Luang district, Pathumtani	---	101	50	Face-to-face in-depth interviews/6month period
Sambatsawat, et al., 2014 [6]	Phimai, Nakhon Ratchasima	C	33	46 (±9.38)	Blood cholinesterase level tested by Testmate ChE (Model400)/24hr/15days/30 after application
Ooraikul, et al., 2011 [7]	Ubon Ratchthani	C	110	15 to 79	Face-to-face questionnaire
Taneepanichskul, et al., 2012 [8]	Hua Rua sub-district, Ubon Ratchthani	---	35	56.3 (±11.1)	Face-to-face interviews
Norkaew, et al., 2013 [9]	Ubon Ratchthani	----	330	_	24 hr indoor air sampler and wiping surface residues with 40% ISO-propanol gauze pads
Norkaew, et al., 2015 [10]	Ubon Raththani	C	90	50-59	Blood enzymes erythrocyte cholinesterase (AChE), and plasma cholinesterase (PChE) were used as measurement tools
Kukreja, et al., 2015 [11]	Hua Rua sub-district, Ubon Ratchthani	___	271	Avg 50	Questionnaire
Taneepanichskul, et al., 2014 [12]	Northern part of Thailand	___	39	30 to 39	Farmer urine samples, pre and post application
Wongwichit, 2010 [13]	Nan	C/Quasi experimental	407	45 to 54	Face to face interviews with questionnaire/ risk communication model/ within 6 months
Wongwichit, et al., 2012 [14]	Namtok Sub-district, Nan	C	407	35-53	Face to face interview with questionnaire
Jaipiem, et al., 2009 [15]	Bang Rieng	C	33	Avg 39	Air samples
Jirachaiyabhas, et al., 2004 [16]	Bang Rieng, Songkhla	Case Study (CS)	33 traditional farmers, 40 Integrated pest managment (IPM)	36-55	Questionnaire
Kunstadtler, et al., 2001 [17]	Chiang Mai	---	582	15 and up	Questionnaire survey
Wilaiwan, et al., 2012 [18]	Nakhon Nayok	C	70	Ave 42.40 (±9.42)	Cholinesterase level was tested by Ellman method, Test-mate ChE (Model 400)
Jirachaiyabhas, et al., 2004 [19]	Bang Rieng, Songkhla	CS	33	20 to 65	The NIOSH Manual of Analytical Methods Number 5600: Organophosphorus pesticides was applied to analyze 33 air samples

assessments. Studies that were original articles published after Jan 2009, evaluated summaries of pesticide exposure on Thai farmers were sorted into categories based and compared using the following criteria: (a) study design; (b) sample size; (c) age of participants; (d) exposure assessment; (e) levels of exposure to compounds; (f) effects observed. The qualitative data used to complete this systematic

Table 2 Results of study populations of rice farmers

Summary of studies investigating rice cropping system exposures to pesticides		
First author (year)	**Study population**	**Study results**
		PYRETHROIDS (PYR)
Fiedler, et al., 2015 [20]	Twenty-four children from a rice farming community (exposed) and 29 from an aquaculture (shrimp) community (control)	Dialkylphosphates (DAPs), 3,4,5-trichloro-2-pyridinol (TCPy), and pyrethoid (PYR) were not significant predictors of adverse neurobehavioral performance.
Rohitrattana, et al., 2014 [21]	53 participants aged between 6 and 8 years old were recruited from rice farms and aqua cultural areas.	Both participant groups had slightly increased urinary PYR metabolites during the wet season compared with the dry season. PYR use in rice farms and households may be significant sources of PYR exposure among children living in agricultural areas.
		ORGANOPHOSPHATE
Sapbamrer and Nata, 2014 [3]	182 rice farmers (exposed subjects) and 122 non-farmers (controlled group)	Occupational pesticide exposure and agricultural tasks in the paddy field may be associated with the increasing prevalence of respiratory tract and muscle symptoms.
Sombatsawat, et al., 2014 [6]	33 male farmers and average age, 46 years old.	Reported their adverse health effects related to gastrointestinal system, urinary system, eye, skin, and central nervous system. Twenty four hours after first application, significant association in eye symptoms Rice farmers applied pesticides at the beginning; both AChE and PChE level were abnormal and self-recovering to normal level by time.
Rohitrattana, et al., 2014 [22]	53, 6–8- year-old participants, 29 participants, living in aqua cultural farming communities	Frequency of OP application on rice farms and living in a rice farming community were significant predictors of urinary DAP metabolite levels. Primary pathways- related to proximity to rice farm, being with parent while working on a farm, playing on a farm, and the presence of observable dirt accumulated on the child's body.
		RISK BEHAVIOR/PERCEPTION
Raksanam, et al., 2014 [5]	101 rice farmers in Khlong Seven community	Exposure resulted from the misuse of pesticides, erroneous beliefs of farmers regarding pesticide toxicity, the use of faulty spraying equipment, the lack of proper maintenance of spraying equipment, or the lack of protective gear and appropriate clothing.
Santaweesuk, et al., 2014 [1]	145 rice farmers	Farmers perceived health risk of occupational hazards on moderate. The pesticide risk perception was high, first of health risk perception. current occupation and farm size variables for exposure

review were collected through open-ended interviews, focus group discussions, and observation. An open-ended interview schedule was used to guide the interviews and focus group discussions. Table 1 provides a data analysis of chosen studies for systematic review. The interviews and focus group discussions conducted on Thai farmers were performed by a research team whose members were trained in interviewing techniques and briefed on the interview and discussion topics. The research team members included professors of public health and health sciences, medical doctors and health care workers, nurses, and health care volunteers who had worked and lived in the study area over the study period.

RESULTS

Thirty six articles were identified using the inclusion criteria described in the previous chapter, 9 of which analyzed exposure to OP pesticides, 6 analyzed exposure due to health risk and health risk behavior, and 6 analyzed both exposure to OP pesticides and Health Risk behavior. Cross sectional studies were the most frequent design. Seven of the studies focused on rice farming systems and the effects on farmers or their families. Eight studies focus on chili cropping systems and the effects on farmers and their families. Out of the 36 studies, 23 were included from the review for the following reasons: the study did not assess rice, chili, maize or other vegetables. Of the 23 included studies, 7 investigated pesticide exposure on rice farms 2 of which investigated indirect pesticide exposure to children of rice farmers. Eight studies investigated pesticide exposure of Chili farmers, 1 of which was indirect exposure of children of chili farmers and 2 studies evaluated pesticide exposure on maize farms and 6 investigated pesticide exposure in other vegetable systems. Results of study populations in chosen articles are summarized in Table 2, 3, 4 and 5.

Table 3 Results of study populations of chili farmers

Summary of studies investigating chili cropping system exposures to pesticides		
First author (year)	**Study population**	**Study results**
		ORGANOPHOSPHATES (Ops)
Ooraikul S , et al., 2011 [7]	110 local people (45 males and 65 females)	Risk characterization of chlorpyrifos did not exceed an acceptable risk ratio (hazard quotient, but risk characterization of profenofos exceeded an acceptable risk ratio. Local people in this area might be getting non-carcinogenic adverse health effects from profenofos residues in chili.
Taneepanichskul, et al., 2012 [8]	38 chili farmers	The main relationship between pesticide exposure and urinary metabolite was found to have been relevant to dermal exposure. Chlorpyrifos and profenofos residues were detected on dermal patches, face wipes, and hand wipe samples
Taneepanichskul, et al., 2010 [2]	35 farmers (26 men and 9 women)	HQ of farmers was lower than the acceptable level). Both of the HQ for male and female farmers were lower than the acceptable level.
Taneepanichskul, et al., 2014 [12]	35 male farmers and average age, 46 years old	Chili-growing farmers in this area might be exposed to pesticides due to their pesticide using behavior. Most participants only rarely used protective equipment.
Norkaew, et al., 2013 [9]	108 households of farm and non-farm families	Pesticides used in farms have contaminated the indoor environment and can be tracked in by clothes, shoes and air drift. Chlorpyrifos pesticides were detected in air samples, Chlorpyrifos and pirimiphos-methyl were detected in surface residue samples
Norkaew, et al., 2015 [10]	Ninety elderly people living in agricultural areas, 50 to 59 years old	Described an association between pesticides exposure and Parkinsonism. Prevalence of abnormal AChE and of PChE levels
		ORGANOCHLORINE
Kukreja, et al., 2015 [11]	271 participants that consisted of elderly farmers with average of 50 and above, both current and former	Combination and use of organochlorine and herbicides were the strongest risk factors Parkinsonism. Long term exposure to pesticides particularly organochlorine and all groups of herbicides had begun to cause the symptoms of Parkinsonism among the farmers.
		RISK BEHAVIOR
Praneetvatakul, et al., 2015 [23]	200 Thai farmers growing hot (chili) pepper and tomato	Pesticide use is positively associated with lower levels of pesticide knowledge and higher levels of risk-aversion.

Table 4 Results of study populations of maize farmers

Summary of studies investigating maize cropping system exposures to pesticides		
First author (year)	**Study population**	**Study results**
		ORGANOPHOSPHATES (Ops)
Wongwichit, 2010 [13]	407 participated in the survey	Maize farmers have high knowledge, positive attitude, good practices, but the maize farmers still had herbicides poisoning symptoms. Did not use the personal protective equipment.
Wongwichit, et al., 2012 [14]	407 farmers	Paraquat poisoning toxic symptoms between group after intervention were significantly different in burn nose, eye irritation, tear drop, and mucus symptoms Affective in increasing the knowledge, attitude, and practice of paraquat use and exposure and significantly increases full compliance of PPE use after intervention

Table 5 Results of study populations of vegetable farmers

Summary of studies investigating vegetable farmers exposures to pesticides		
First author (year)	**Study population**	**Study results**
		ORGANOPHOSPHATES (Ops)
Jaipieam, et al., 2009 [15]	33 vegetable growers	Indicate that the vegetable growers may be at risk for acute adverse effects via the inhalation of chlorpyrifos and dicrotofos during pesticide application, mixing, loading, and spraying.
Jirachaiyabhas, et al., 2004 [16]	Thirty-three air samples were collected during pesticide spraying	Traditional farmers 'absorbed more of pesticide via Inhalation than did IPM farmers.
Kunstadter, et al., 2001 [17]	Three highland communities and Hmong in urban Chiang Mai were studied. 582 Hmong adults	20-69% of 582 Hmong adults with risky or unsafe levels of cholinesterase inhibition, exposure to organophosphate and carbamate pesticides. Exposure rates are as high among those' who do not actually apply pesticides as among those who do exposure by routes in addition to direct contact.
Jaipieam, et al., 2009 [24]	100 water samples were collected and subjects were asked to complete a survey	Agricultural communities were exposed to pesticide residues under the oral chronic reference dose. People in agricultural communities may be exposed to significantly greater levels of pesticides than non-agricultural populations during the dry and wet seasons.
Wilaiwan, et al., 2014 [18]	Farmers (n=35) and non-farmers (n=35)	The farmers were significantly associated with increase eye symptoms, central nervous system (CNS) symptoms, respiratory system symptoms, and glands. The AChE level was significantly associated with CNS symptoms. The PChE level was significantly associated with eye symptoms, CNS symptoms, respiratory system symptoms, and glands symptoms.
Jirachaiyabhas, et al., 2004 [19]	33 traditional and 40 integrated pest management (IPM) farmers Thirty-three air samples were collected	Significant difference in the level of exposure between the traditional farmers and the IPM farmers. Traditional farmers were exposed to higher levels of the pesticide(s)

Health risk, pesticide exposure and perception in farmers

On rice and chili farms most farmers use organophosphates on their crops and normally apply more than what is recommended whereas maize farmers tend to spray herbicides on their farms. In rice farms, studies suggest that occupational pesticide exposure and agricultural tasks in the paddy field may be associated with the increasing prevalence of acute adverse health effects such as dizziness, fatigue and respiratory infection [3]. Some farmers reported their adverse health effects related to gastrointestinal system, urinary system, eye, skin, and central nervous system [6]. Major risk factors related to agrochemical exposure resulted from the misuse of pesticides, or improper use of personal protective equipment (PPE). The farmers beliefs regarding pesticide toxicity along with lack of appropriate clothing increase health risk not only among farms but families as well. Findings suggest that PYR use in rice farms and households may be significant sources of PYR exposure among children living in agricultural areas [20]. Metabolite levels among children who live in rice farming communities were strongly influenced by farming activity, such as not washing clothing properly. Household environments and child behaviors also suggest that these are primary pathways to indirect exposure to children living near rice farms [20]. Overall the original hypothesis was the rice farmers were at higher risk from pesticide exposure than chili and rice farmers. Based on results compared from AChE and PChE levels in farmers it is suggested that rice is farmers indeed have a higher risk of pesticide exposure resulting in adverse health effects.

Studies on chili farms suggest that the lack of Knowledge, Attitude and Practice (KAP) has put chili farmers at high risk of pesticide exposure. Chili plants are large sometimes growing above the farmer in 1 study organophosphates such as chlorpyrifos and profenofos residues were detected on dermal patches, face wipes, and hand wipe samples suggesting that farmers are not properly using pesticides nor (PPE) [8]. Chili farmers participating in the studies only rarely used protective equipment which most applied pesticides weekly. Use behavior would suggest that chili-growing farmers may have high risk of exposure. The lack of Knowledge, Attitude and Practice (KAP) among chili farmers has shown the long term exposure to pesticides particularly organochlorine and all groups of herbicides had begun to cause the symptoms of Parkinsonism among the some farmers [10]. KAP studies have not only suggested exposure to farmers but and also indirect pesticide exposure have contaminated the indoor environment of households [9].

The paucity of maize studies suggest that much more research needs to done on the subject. However what can be suggested from current studies is that the majority of maize farmers have high knowledge, positive attitude, good practices, but the maize farmers still had herbicides poisoning symptoms [14]. Due to discomfort most maize farmers did not use personal protective equipment which is a risk behavior common amongst most farmers in Thailand [14].

DISCUSSION

This study was a systematic review about the health risks of pesticide exposure in agriculture systems in Thailand. Participants came from farming and non-farming communities across the country from different cropping systems. Many factors were addressed such as pathways of exposure, farmer perceptions, and risk behaviors among farmers of the three major cropping systems; rice, chili and maize. Thailand having a major role in exporting food is drastically increasing their dependency on pesticide exposure most of which are not regulated and improperly applied to agriculture resulting in higher risk of exposure. With the growing demand of crops Northern Thailand is the largest maize producing region, accounting for about 49% of the national acreage, followed by the Northeast Region with 26%. The Central Region accounts for 24% of the total maize area. Thailand has plans to further increase the land available for rice production, with a goal of adding 500,000 hectares to its already 9.2 million hectares of rice-growing areas. Pesticide exposure in the last decade has increased drastically along with the rising demand of crop output. Organophosphates are prevalent on rice and chili farms and most studies on organophosphates show that farmers do suffer from adverse health effects while children are also exposed indirectly. Contaminations of Indoor environments by farm used pesticides were determined to be the result of improper methods of washing and putting away spraying equipment and clothes. It is suggested that possible indirect pesticide exposure to families that live in the vicinity comes from these bad habits of not properly washing equipment or clothes and can also result in indirect exposures in the household. Furthermore, a study has shown the main pathway for children may be from activities done around farms which track dirt into households as a result cause children in rice farming communities to have higher urinary OP metabolites than children in non-farming communities [21]. Maize farms rely of herbicides however not much research has been done in the field creating a knowledge gap of pesticide exposure and it's relation to health risk on maize farmers. Knowledge, attitudes, and practice (KAP) is suggested to be one of the most important factors to be researched for a better understanding on what causes high prevalence of pesticide exposure. Most studies reflect on the results of pesticide exposure being the result of improper use of personal protective equipment (PPE) and suggest guidelines and management strategies be implemented to increase the knowledge attitude and practices of farmers. Continued studies should be done on KAP, as it is suggested to be the catalyst of change in the rate of pesticide exposure and chance of exposure.

CONCLUSSION AND RECOMMENDATION

This review included studies with a wide variety of different designs and methods to evaluate health risks of pesticide exposure. In some studies it was suggested that men having a higher average daily dose (ADD) of pesticide exposure than women, however looking at demographic data such as gender it was concluded that there is no disparity between men and woman being exposed as both groups are equally exposed. Looking at the comparison among rice, chili, maize and other vegetables it can be suggested that the pesticide residues on chili exceed the acceptable levels suggested by the hazard quotient (HQ > 1). However, looking into comparisons of studies between AChE and PChE levels in rice and chili it can be suggested that rice farmers are at a higher risk of exposure than chili maize and other vegetable farmers. The original hypothesis stating rice farmers were at higher risk than chili and maize farmers can be suggested by the comparison of AChE and PChE as a biomarker. Studies in which biomarkers of OP exposure were collected observed adverse neurobehavioral effects associated with lower AChE activity and neurologic symptoms such as dizziness and blurred vision. AChE activity was significantly lower median in rice farmers but significantly higher prevalence of difficulty in breathing and chest pain. In one study both AChE and PChE levels were abnormal and self-recovering to normal levels with time. Collectively most rice, chili and maize farmers do not use personal protective equipment to the best of their ability to accommodate the increase of pesticide applications on crops which leaves opportunity for pesticide exposure. The use of gloves, masks and proper clothing are essential to reducing pesticide exposure in farming communities yet we have not seen this practice becoming a priority. Spraying happens all year round in multiple applications and the neglect of proper PPE use is not only an occupational hazard but also an environmental one with indirect consequences on farmers' families as well. Predominately seen in the rice studies children are becoming exposed due to the practices of not properly cleaning farming equipment prior to being used. Rice farming families tend to live closer to paddies and child behaviors have influenced OP metabolite levels. Knowledge, attitude and practices along with PPE are essentially important to decrease pesticide exposure among all cropping systems in Thailand. When looking at the data collected it has been observed that, AChE and PChE levels in farmers suggest that rice farmers have higher risk of pesticide exposure and adverse health effects compared to chili and maize farmers. It is suggested that with this data, a public health education center for programs be implemented in Universities in Thailand. Programs like this are already modeled and work very well in the United States and European Union which produce similar agriculture. Recommendation to reduce risks starts with intervention to increase Knowledge, Attitude and Practice (KAP) of all farmers in Thailand specifically rice, chili and maize farmers. It is suggested, due to paucity of studies, that there be more focus on maize cropping systems in Thailand to grasp a more clear association between health risks and pesticide exposure. Indirect exposed groups, such as children, should be included for additional rice, chili and maize studies as well.

In conclusion the research suggest that rice farmers have a higher health risk than chili and maize farmers based on AChE and PChE levels in farmers. Agricultural communities may be exposed at greater levels than that of non-agricultural communities during both the wet and dry seasons so further research should be done with control groups to show the disparity between farming community pesticide exposure and non–farming communities.

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